FINAL DRAFT

INTERSECTION IMPROVEMENT ANALYSIS
SR 20 / SR 49 FROM EMPIRE STREET
TO THE BRIGHTON STREET OVER-CROSSING

Prepared for the NEVADA COUNTY TRANSPORTATION COMMISSION

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EXECUTIVE SUMMARY

Several key conclusions and recommendations for mitigation within the study area are summarized in this report. LOS D or better conditions has been the goal. The study area consists of the street network illustrated in Figures 1.1 and 2.2, consisting of SR 20 from Brighton Street over-crossing to the Auburn Street ramps, Mill Street from the SR 20 WB Ramps to McCourtney, and McCourtney from Mill Street to Brighton Street. The NCTC MINUTP traffic model was updated to reflect current traffic model forecasts for the Year 2020, 2040, and Grass Valley General Plan (GVGP) Buildout (see Working Paper No. 4). Several analyses corresponding with this traffic modeling effort were completed for the SR 20 / Mill Street / Mc Courtney corridors in the vicinity of the Empire Interchange. It yielded a variety of results as follows:

The surface street study intersections need mitigation before the Year 2020. Mitigations for the same generally consist of coordinated signal systems and installations, with the exception of the Mill Street corridor where modern roundabouts exceed the ability of signal systems to mitigate the traffic forecast impacts. The Empire Interchange can generally handle Year 2020 projected traffic volumes at satisfactory levels of service, but will fail sometime between the Year 2020 and the Year 2040. Since the need for improvements is sometime beyond the 20 year window used for programming capital improvements to the transportation system, the cost of related improvements documented in this report will not be programmed for several years.

Year 2040 and GVGP Buildout conditions were analyzed as well for all locations. It was determined that the Empire Interchange signalized intersections will eventually fail. Tables 1.2, 1.3, 1.4, 1.4b, and 1.5 document intersection analyses for Year 2020, 2040 and Buildout conditions, with variations in analysis using "permissive" signal phasing control[1]. Permissive signal control is generally not acceptable to Caltrans under the conditions present at the Empire Interchange. It would be acceptable on Mill Street. After exhausting all typical mitigation alternatives, it became apparent that more intensive mitigations needed to be considered, studied, and analyzed. The results are in the following summaries.

[1] Permissive signal phasing allows for an "all green" signal condition so that left turns can continue to clear the intersection as long as there is a gap in opposing through traffic. This situation is typically recommended for just single lane approaches, however.

Empire Interchange

In several different alternative analyses, we sought mitigation seeking solutions other than the typical and/or permissive intersection signal installations, or intersection / road widening (which is not possible in many cases). Our analyses encompassed each of the six study intersections as well as the freeway segments. At the Empire Interchange we studied the results for two additional types of improvements:

1. The Single Point Urban Interchange (SPUI)
2. Modern Roundabouts

As a result, we found that either of these solutions will work satisfactorily for Year 2040 or the ultimate future GVGP Buildout traffic, if designed as depicted in this report. The operations of the SPUI alternative would work better than the modern roundabout alternative (based on our visual inspection and comparisons using SimTraffic software). Figure 6.1 shows how a SPUI works, and Figure 6.2 illustrates how it could be installed at the Empire Interchange location. If a SPUI is installed, LOS C or better conditions would exist at the SPUI intersection even with Buildout volumes. The estimated SPUI cost would be $4,608,000 (see Table 6.1 for a detailed cost estimate break down).

In lieu of building a SPUI, it is possible that a modern roundabout could be installed at the northbound ramp of the Empire Interchange at a much lesser cost ($880,000 detailed in Table 5.1), but with a bigger impact to pedestrian and bicycle traffic, as well as long delays to the westbound Empire Street approach. This improvement would deliver similar level of service results (LOS C/D) to mainline SR 20 westbound vehicular traffic flow.

One of the potential drawbacks would be lower levels of service for side street traffic due to delays, specifically, the Empire Street westbound approach and the northbound offramp approach. Both of these approaches would necessarily have “yield on entry” control into a busy roundabout, forcing a wait for gaps in traffic. While the overall average level of service for the roundabout would be LOS D or better, the yield-on-entry control approaches would likely experience LOS E conditions waiting for a gap in traffic to enter the roundabout. The mainline SR 20 westbound traffic flow would operate at LOS A conditions.

In Table ES.1 which follows, various Pros and Cons are identified for three interchange mitigation options. Pros are ranked on a scale of 0 to 5 using positive numerical values. Cons are also ranked on a scale of 0 to 5 using negative numerical values. In this manner, some positive results of one particular alternative can be canceled by negative results. The end result will be a numerical ranking for each alternative which is either less than zero (indicating that its negative features outweigh its positive ones), or greater than zero (indicating a majority of positive features).

Table ES.1
Comparison of Empire Interchange Improvements

	Description	Exist. SIGNAL	SPUI	ROUND ABOUT
PROS	High Capacity for all Buildout Traffic ?	**0**	**3**	**1**
	High Capacity for all Year 2020 Traffic ?	**0**	**5**	**5**
	Straight-forward to Construct ?	**1**	**1**	**1**
	Typical Intersection Geometry ?	**1**	**1**	**0**
	Pedestrians / Bikes can safely navigate ?	**2**	**2**	**0**
	Low Cost ?	**3**	**0**	**2**
CONS	Low Capacity for Year 2020 traffic ?	**-5**	**0**	**0**
	Not friendly to Peds and/or Bikes ?	**0**	**0**	**-2**
	Expensive ?	**0**	**-3**	**-1**
	Delays to Side Street Approaches ?	**-3**	**0**	**-2**
	Construction impacts to traffic flows ?	**0**	**-1**	**-1**
	Higher Accident Potential ?	**0**	**-1**	**0**
	TOTAL POINTS	**-1**	**7**	**3**

Source: PRISM Engineering

The SPUI alternative was ranked with the highest score, due to superior performance on most independent considerations for the Interchange, including very high capacity, more typical design, and the ability to work with bikes and peds. For this reason, we are recommending the SPUI be planned in the long-term category (sometime between Year 2020 and 2040) for a future mitigation at the Empire Street Interchange, at a cost of $4,608,000.

Mill Street Corridor

The Mill Street corridor in the study area consists of the closely spaced intersection combination of the SR 20 WB Ramps, and Mc Courtney Road. Based on the inability to adequately mitigate these two intersections with a signalized solution (left turn conflicts are too high at the Mill St / Mc Courtney intersection and cause excessive delays and queues), it was necessary to design a modern roundabout system that takes advantage of narrow roads and existing limited right-of-way between and at each intersection. The roundabouts, in this case, maximize capacity, and keep traffic moving at a steady flow rate. LOS C or better conditions would exist with the modern roundabout improvements designed and depicted in Figure 5.2. Some cut and fill would be needed at each location, as well as new pavement, etc., as detailed in Tables 5.2 and 5.3. The cost would be $372,400 for the Mc Courtney / Mill St. roundabout, and $230,900 for the SR 20 WB Ramps / Mill St. roundabout. Total cost: $603,300.

Mc Courtney Road / Brighton Intersection

This intersection will require a signal and typical intersection lane approach expansion when Brighton Road is extended southerly into undeveloped lands on the south side of Mc Courtney Road. Brighton Road south would be a four lane road transitioning into a two lane road, with specifics to be determined at time of development based on a detailed traffic analysis of proposed development. Dual left turn lanes from westbound Mc Courtney Road into the new development (Brighton Road south) would be needed. Mc Courtney Road west of Brighton Road would remain as a two lane arterial. A signal would need to be installed at this location.

SR 20 Freeway Segment from Empire to Auburn Street

This segment of freeway is expected to fail after the Year 2020 (sometime near when the Year 2040 traffic volumes are realized). The main reason for the breakdown in traffic operations is due to the high merge conflicts of traffic getting onto the freeway from the Empire Interchange northbound ramp. The mainline freeway traffic would already be at “capacity,” and the oncoming Empire Street traffic would aggravate an already slow freeway traffic speed. One potential solution for reducing traffic volumes is to construct additional “parallel” roadways to the SR 20 freeway. For this reason, the so-called “western bypass” was explored as a possible solution. Our traffic modeling and analyses showed that there was merit to this mitigation, and that it would reduce the amount of traffic from Grass Valley that would otherwise impact this overloaded section of freeway. A 10-15% reduction in surface street to freeway traffic was realized, as traffic patterns shifted with the new bypass connection to SR 20 one mile west of Brighton Street. This reduction would help keep the freeway traffic moving. For this reason, it is recommended that future planning studies in Grass Valley include the western bypass as a planned improvement; an improvement that correlates with the increased intensity in the City’s General Plan densities. As an alternative to construction of this expensive bypass and freeway interchange, a reduction in land use intensity within Grass Valley could serve as a mitigation to traffic impacts for the buildout condition. As a third alternative, the Golden Center Freeway itself could be widened to three lanes in each direction, but the environmental and political issues associated with such widening of the freeway and its corridor would be so great as to probably render it an infeasible option.

Recommendation: Include the Western Bypass in future planning studies, to provide additional north / south connections crossing SR 20 west of Brighton

Street.

Intersection Improvement Summary

All intersections in the study area would need signalization as a minimum mitigation for Year 2020 traffic volumes, with the exception of Mill Street at McCourtney and the SR 20 WB Ramp, which would require modern roundabout installation to work satisfactorily. The following table summarizes the various improvements recommended for each location.

Table ES.2
Intersection Improvement Recommendation

Intersection Location	Recommended Improvement	Year Needed At or Before
1. Brighton Street at McCourtney Road	**Signal, Widening**	**2020**
2. McCourtney Road at S.R. 20 EB Ramps	**Signal**	**2020**
3. Mill St / McCourtney / Allison / Freeman	**Roundabout**	**2020**
4. Mill Street at S.R. 20 WB Ramps	**Roundabout**	**2020**
5. Empire Street at S.R. 20/49 SB Ramps	**SPUI**	**2040**
6. Empire Street at S.R. 20/49 NB Ramps	**SPUI**	**2040**

Source: PRISM Engineering

INTRODUCTION

The Empire interchange in Grass Valley is the hub for regional traffic, with SR 20 heading to the west and the Golden Center Freeway traveling north/south. The Empire bridge over the freeway is wide, but short, the two freeway ramp intersections being very closely spaced, similar to most other tight-diamond interchanges in the County along the Golden Center Freeway (such as McKnight). This presents a traffic operations problem, if this were the only problem with the corridor. However, there are other closely spaced intersections and freeway ramps such as the Mill Street corridor between McCourtney Road and the SR 20 WB ramps. These locations have limited capacity for future traffic volumes. Several alternatives were explored to mitigate future traffic volumes. Roundabouts and advanced signal systems, including the Single Point Urban Interchange were investigated to handle ultimate traffic volumes.

Previous studies in the area have not specifically addressed the unique travel patterns for the section of S.R. 20 between S.R. 49 and the Brighton Street over-crossing. The 1994 Sub-Regional Transportation Study was based on an older Countywide model including Truckee, and since the revised west-slope model was developed, projections in the area have been refined. The recalibration of the model in 1995 was updated in subsequent years with land use file refinements, and is most current to the Year 1999. The Nevada County Operations Study in 1996 took a detailed look at the McCourtney Road corridor, and provided mitigations for that road, but did not address the S.R. 20 corridor from Empire to Brighton. There is a need to provide the level of detail necessary in a comprehensive study, so that decisions can be made and planned for the corridor from the Empire interchange to the Brighton Street over-crossing. In addition, the freeway operations for the other segment of freeway north of Empire (S.R. 20/49 from Empire Street to the Auburn Street ramps) needs further study.

The purpose of this study will be to forecast the appropriate future traffic volumes for the study corridor, for the 20-year window (Year 2020), the Year 2040, as well as Grass Valley General Plan Buildout. The traffic model was updated with the latest Grass Valley General Plan update land uses, and the model was checked to make sure that all additional trips were assigned to the street system. The model's trip generation internal/external percentages were modified to handle the additional buildout trip generation. In this manner, the full impact of future attractions will be realized, and a true deficiency for the corridor identified.

WORKING PAPER NO. 1

Task 1 Analysis of Intersections

Overview

The study area consists of several freeway ramp systems, at grade signalized intersections, as well as at grade stop-controlled intersections. There are several potential solutions to mitigation of existing and future projected traffic volumes. This paper defines several existing and future scenario analyses results for at grade intersections. Other working papers will provide additional details for mitigations such as freeway or ramp modifications, freeway auxiliary lanes, or even the use of the modern roundabout as a replacement for at grade signalized or unsignalized intersections or ramps.

Introduction

The following intersections were analyzed for levels of service for p.m. peak hour, a.m. peak hour, existing conditions, and various scenarios of future conditions:

1. Brighton Street at McCourtney Road
2. McCourtney Road at S.R. 20 EB Ramps
3. Mill Street / McCourtney Road / Allison Ranch Road / Freeman Lane
4. Mill Street at S.R. 20 WB Ramps
5. Empire Street at S.R. 20/49 SB Ramps
6. Empire Street at S.R. 20/49 NB Ramps

The a.m. peak hour in the study area overall (as measured from direct comparisons of Caltrans mainline freeway counts on a variety of different times of the year) is much lower than the p.m. peak hour. There are some ramp systems which have volumes that remain fairly constant between the two peak time periods, but overall the p.m. peak hour volumes on the freeway are higher by a factor of two (when comparing 5-6pm with 7-8am).

More details on the a.m. peak hour factors are given in a footnote(*a*) at the end of this section, Working Paper No. 1.

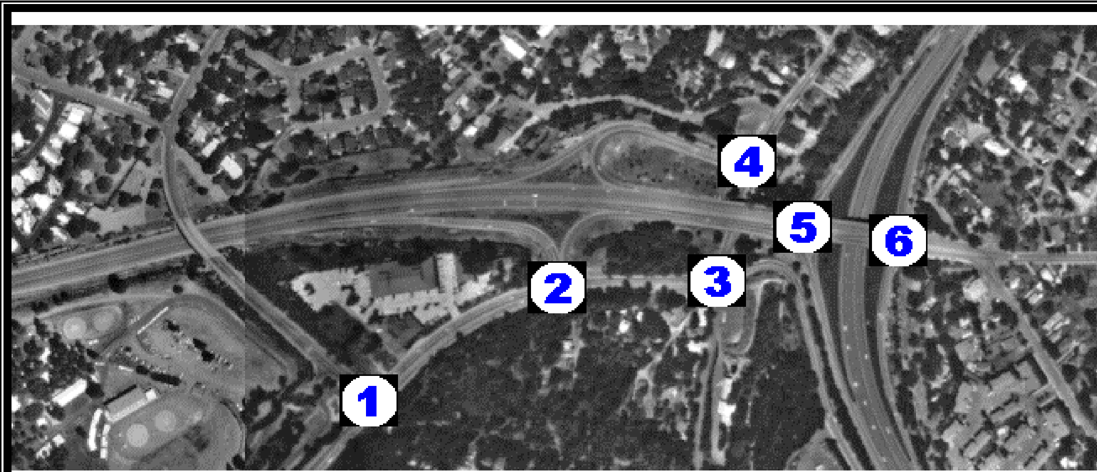
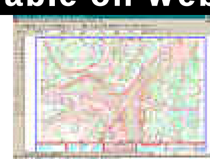


Figure 1.1

Study Area Intersection Locations 1-6

Topo Map of Left Study Area
(Full size PDF graphic available on web site)



Topo Map of Right Study Area
(Full size PDF graphic available on web site)

Figure 1.2 Study Area and Topo Maps

Existing Year 2000 Conditions

New PM Peak hour traffic counts were taken along the SR 20 corridor at all intersections in March of 2000. AM Peak hour data was collected from Caltrans. These were analyzed in various software analysis programs including Synchro Pro, HCS, and SimTraffic. The results are shown in Table 1.1 for individual intersections.

Table 1.1

Intersection Level of Service Analyses Summary for Year 2000

	Intersection	Type of Control	Critical V/C		Side St. Delay		Side St. LOS	
			PM	AM	PM	AM	PM	AM
1	Brighton Street at McCourtney Road	2way Stop	0.25	0.23	12.5	12.3	B	B
2	McCourtney Road at S.R. 20 EB Ramps	2way Stop	0.22	0.22	14.6	12.1	B	B
3	Mill Street / McCourtney Road	4way Stop	N/A	N/A	13.5	12.0	B	B
4	Mill Street at S.R. 20 WB Ramps	2way Stop	0.51	0.17	15.1	10.1	C	B
					Delay		LOS	
5	Empire Street at S.R. 20/49 SB Ramps	Signal*	0.62	0.38	5.4	4.8	A	A
6	Empire Street at S.R. 20/49 NB Ramps	Signal*	0.47	0.51	6.2	9.3	A	A

**Note: Signals are part of a diamond package with 45-60 second cycle lengths, are coordinated and responsive to vehicle volumes on all four approaches to diamond interchange. Yellow times set at 3.5 secs, 1 second all reds on mainline and 0.5 all red on ramps. Delay is reported with Webster's Delay method.*

As can be seen from Table 1.1, the existing p.m. peak hour levels of service for the study area are at LOS C or better conditions. This is based on the 1998 Highway Capacity Manual HCS unsignalized software for intersections 1-4, and SynchroPro for intersections 5-6, both based on the most current Highway Capacity Manual (HCM) methodologies.

The Synchro Pro model was set up with the entire study street network so that the complex traffic flows could be modeled visually. In Figure 1.3 the Synchro network is set forth. This network has the intersection geometry coded in, as well as street speeds and link distances. The software reports levels of service at signalized intersections, and models traffic decel and accel rates at stop sign controlled intersections. Using this software as well as the HCS tool helps to establish a more accurate picture of LOS from different perspectives.

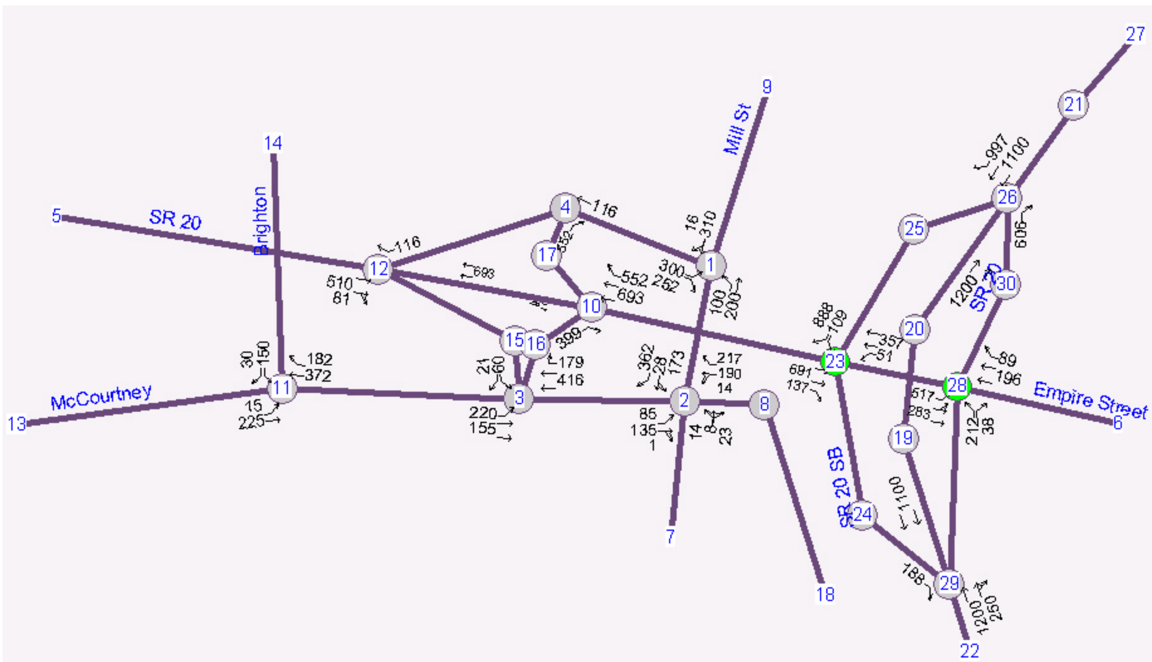


Figure 1.3 SynchroPro Simulation Model Street Network (Node numbers and p.m. peak turn moves)

We contacted Caltrans District 3, Myron Fladlands, to obtain signal timing data and configuration for the Empire diamond interchange signal system. This information was used to program the Synchro model for the two intersections at the NB and SB ramps. LOS A conditions prevail for the existing p.m. peak hour condition.

In Figure 1.4 the Synchro Pro network was converted to the simulation mode using SimTraffic. This tool enables us to visually inspect traffic flows, check for back-ups (vehicle queues), excessive delays, and lane utilization, etc.

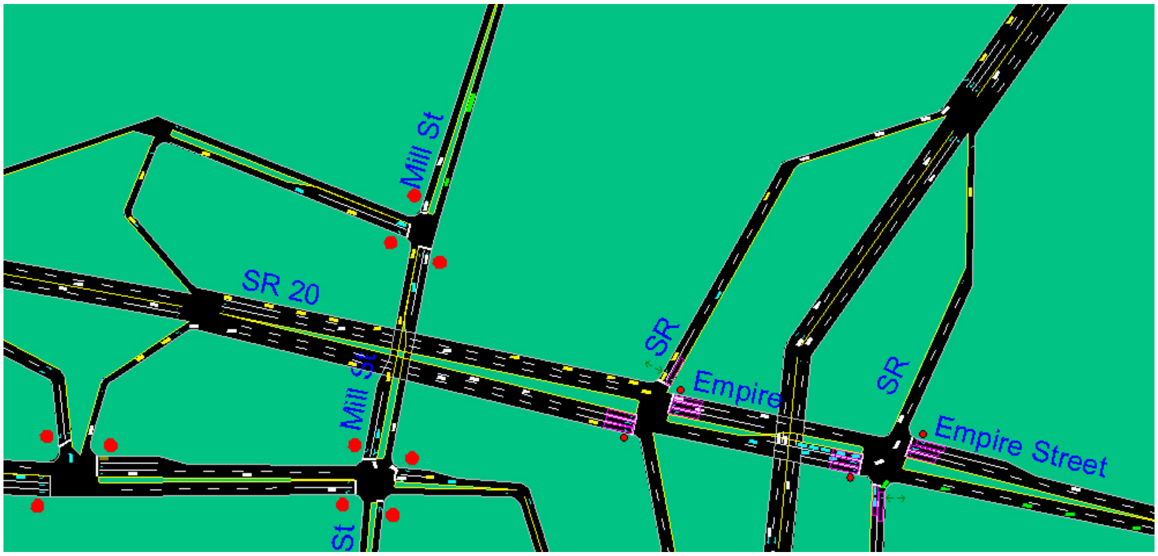


Figure 1.4 SimTraffic Simulation (Existing p.m. peak shown)

The SimTraffic software shows how various sized cars, trucks, buses, and pedestrians interact on the street network based on the traffic volumes and lane geometry entered into the SynchroPro software. For example, if traffic flow on a side street is delayed due to high volumes on the main street, the SimTraffic software shows this, and traffic will back up until a reasonable gap in traffic appears. If slow trucks are a factor in intersection delay, this software can help make this more apparent. If pedestrian conflicts with vehicles at intersections is an issue, the visual feedback can help pinpoint trouble areas. We can use this software to determine when and where a traffic signal or some other alternative traffic control might be able to help traffic flow at a given intersection.

CORSIM Output

The following text file contains the card record files for use in the CORSIM program. This file was created using the SynchroPro street network shown in Figure 1.3 above. The file can be downloaded from the www.prismworld.com web site.

Future Year 2020 Conditions, Unmitigated

The future Year 2020 conditions were derived from the most current NCTC traffic model modified with the most current Grass Valley General Plan Update land uses. The MINUTP model was corrected to properly balance the internal productions and attractions, and these volumes were used in this analysis.

Table 1.2

Intersection Level of Service Analyses Summary for Year 2020 Unmitigated

	Intersection	Type of Control	Critical V/C		Side St. Delay		Side St. LOS	
			PM	AM	PM	AM	PM	AM
1	Brighton Street at McCourtney Road	2way Stop	0.76	0.70	53.5	52.6	F	F
2	McCourtney Road at S.R. 20 EB Ramps	2way Stop	1.32	1.30	433	400	F	F
3	Mill Street / McCourtney Road	4way Stop	N/A	N/A	24.1	21.4	C	C
4	Mill Street at S.R. 20 WB Ramps	2way Stop	0.89	0.30	48.2	32.2	E	D
					Delay		LOS	
5	Empire Street at S.R. 20/49 SB Ramps	Signal*	0.89	0.55	11.2	10.0	B	B
6	Empire Street at S.R. 20/49 NB Ramps	Signal*	0.59	0.64	13.9	6.3	B	A

**Note: Signals are part of a diamond package with 45-60 second cycle lengths, are coordinated and responsive to vehicle volumes on all four approaches to diamond interchange. Yellow times set at 3.5 secs, 1 second all reds on mainline and 0.5 all red on ramps. Delay is reported with Webster's Delay method.*

As can be seen from Table 1.2, the Year 2020 p.m. peak hour levels of service for the study area would fail for side street traffic at three out of six locations studied during the pm peak hour time period. The am peak hour conditions were estimated for this scenario based on ratios between am and pm values for the existing conditions scenario. Two-way stop control locations can be mitigated typically with signalization, modern roundabouts, or a combination of both. Mitigations for the Year 2020 conditions are explored in the next section.

Future Year 2020 Conditions, Mitigated

The volumes from the previous section were analyzed in a mitigated condition for the street network. Since several intersections would require signalization to properly mitigate the failure condition, we utilized the Synchro Pro signalization and traffic simulation software to assess the effectiveness of various mitigations. Since some intersections are closely spaced in the Mill Street and McCourtney corridors, the Synchro software can determine the effectiveness of signal timing and coordination to achieve satisfactory levels of service.

Table 1.3

Intersection Level of Service Analyses Summary for Year 2020 Mitigated with Signals

	Intersection	Type of Control	Critical V/C		Delay		LOS	
			PM	AM	PM	AM	PM	AM
1	Brighton Street at McCourtney Road	Signal	0.49	0.45	15.0	13.9	B	B
2	McCourtney Road at S.R. 20 EB Ramps	Signal	0.36	0.35	2.7	2.7	A	A
3	Mill Street / McCourtney Road	Signal	0.80	0.72	165	149	F	F
4	Mill Street at S.R. 20 WB Ramps	Signal	0.82	0.41	14.1	6.6	B	A
5	Empire Street at S.R. 20/49 SB Ramps	Signal*	0.89	0.55	9.1	10.0	A	B
6	Empire Street at S.R. 20/49 NB Ramps	Signal*	0.54	0.59	13.4	5.8	B	A

**Note: Signals are part of a diamond package with 45-60 second cycle lengths, are coordinated and responsive to vehicle volumes on all four approaches to diamond interchange. Yellow times set at 3.5 secs, 1 second all reds on mainline and 0.5 all red on ramps. Delay is reported with Webster's Delay method.*

Table 1.3 indicates that the future Year 2020 p.m. peak hour levels of service for the study area can be mitigated to LOS D or better conditions with coordinated signal systems installed. If a signal is not installed at the Mill Street / McCourtney intersection (which is currently operating as a four way stop), the SR 20 EB ramps at McCourtney Road will fail at LOS E conditions. This is mitigated by having a set of coordinated signal systems along the McCourtney Road corridor.

Future Year 2040 Conditions, Mitigated

Year 2040 volumes were prepared using a land use projection based on the NCTC's Year 2020 model. The model runs yielded the following results.

Table 1.4

Intersection Level of Service Analyses Summary for Year 2040 Mitigated with Signals

	Intersection	Type of Control	Critical V/C		Delay		LOS	
			PM	AM	PM	AM	PM	AM
1	Brighton Street at McCourtney Road	Signal	0.59	0.54	15.6	14.3	B	B
2	McCourtney Road at S.R. 20 EB Ramps	Signal	0.41	0.40	4.5	4.4	A	A
3	Mill Street / McCourtney Road	Signal	1.42	1.27	275	245	F	F
4	Mill Street at S.R. 20 WB Ramps	Signal	1.01	0.51	47.5	23.5	D/E	C
5	Empire Street at S.R. 20/49 SB Ramps	Signal	0.98	0.61	13.3	8.3	B	A
6	Empire Street at S.R. 20/49 NB Ramps	Signal	0.73	0.79	7.8	8.4	A	A

**Note: Signals are part of a diamond package with 45-60 second cycle lengths, are coordinated and responsive to vehicle volumes on all four approaches to diamond interchange. Yellow times set at 3.5 secs, 1 second all reds on mainline and 0.5 all red on ramps. Delay is reported with Webster's Delay method.*

In all cases, a new signal is required at each intersection to help traffic flow. Table 1.4 reports intersection levels of service which are theoretically possible with protected left turn phasing. Table 1.4b gives the same results with some permissive phasing at the Mill Street intersections where protected phasing does not yield satisfactory results (such as at Mill Street / McCourtney Road where a signal still yields LOS F). The SR 20 EB Ramp intersection with Mill Street is also at an LOS D/E condition even with coordinated signals. This is due to capacity constraints in intersection approach geometry. There is not adequate width to significantly expand intersection approach capacity where it is needed.

Permissive phasing is possible at the two Mill Street study intersections (SR 20 EB Ramp and McCourtney Road), and can help get more traffic through the intersection, thus improving / increasing capacity. The result of this change is shown in Table 1.4b which utilizes the permissive phasing on these two intersections.

Table 1.4b

Intersection Level of Service Analyses Summary for Year 2040 Mitigated with Signals, Permissive Phasing

	Intersection	Type of Control	Critical V/C		Delay		LOS	
			PM	AM	PM	AM	PM	AM
1	Brighton Street at McCourtney Road	Signal	0.59	0.54	15.6	14.3	B	B
2	McCourtney Road at S.R. 20 EB Ramps	Signal	0.41	0.40	4.5	4.4	A	A
3	Mill Street / McCourtney Road	Signal (permissive)	0.83	0.74	14.3	12.7	B	B
4	Mill Street at S.R. 20 WB Ramps	Signal (permissive)	1.11	0.56	29.9	15.0	C	B
5	Empire Street at S.R. 20/49 SB Ramps	Signal	0.98	0.61	13.3	8.3	B	A
6	Empire Street at S.R. 20/49 NB Ramps	Signal	0.73	0.79	7.8	8.4	A	A

**Note: Signals are part of a diamond package with 45-60 second cycle lengths, are coordinated and responsive to vehicle volumes on all four approaches to diamond interchange. Yellow times set at 3.5 secs, 1 second all reds on mainline and 0.5 all red on ramps. Delay is reported with Webster's Delay method.*

SimTraffic Visual Analysis

Although the levels of service for the optimized and coordinated signal system indicate that satisfactory levels of service are possible in Table 1.4b, the simulated traffic volumes for this Year 2040 scenario indicate that there will be problems along the McCourtney and Mill Street corridors, as well as the Empire Interchange. The intersection analysis and level of service rating in intersection analysis software is not sensitive to the traffic operations on the link segments between intersections. The SimTraffic software tool is used in addition to SynchroPro to provide some sensitivity to link segment operations, lane blockages, queuing, etc. The SimTraffic software, which further visually analyzes the traffic volumes with flow rate algorithms, can show where left turn pocket overflows will occur, and how this blocking of traffic extends blockages back into adjacent intersections, causing failure. The Year 2040 volumes appeared to have failure on several link segments inspected with SimTraffic, even though the intersections themselves can theoretically handle traffic volumes if coordinated properly. Most link segments in the study area are constrained by short distances between intersections, as well as constraints on road width, especially on Mill Street.

This failure in the SimTraffic visual analysis of roadway volumes indicates that the Year 2040 traffic can not be mitigated with conventional signalization at the two Mill Street study intersections. Modern roundabout mitigations are investigated as an option later in this report, and found to be a satisfactory solution to long term traffic mitigation needs.

The Empire interchange intersections were analyzed with the SB ramp as a "free right" unconstrained movement. If the SB right turn movement is signalized in any way, the level of service for this intersection drops to LOS F conditions. Since there is a receiving auxiliary lane on SR 20 for this off ramp traffic, this intersection was analyzed with the movement set as "free right" in the software. However, given the short merge distance in the auxiliary lane (500 feet), as well as the diverging traffic conflict from SR 20 conflicting with this movement, there is potential for delays, which would affect overall operations of vicinity surrounding this intersection. For this reason, the intersection analysis could be considered somewhat liberal based on using the "free right" designation despite the potential operational issues just downstream. We know from analysis that some slowing of traffic will occur from the SB off ramp merging with SR 20 traffic, and the result will be operational side-effects to the Empire Interchange. We utilized the SimTraffic software to check the operations of this and other movements, as well as the adjacent link segments, to make sure that our analysis was conservative.

It appeared from the SimTraffic analysis that the SR 20 freeway was able to handle the traffic volumes in the westbound direction for the Year 2040 volumes, but the weaving analysis in Working Paper Section 2 indicates that a traffic operations speed problem will exist by the Year 2020 due to excessive weaving to and from the ramp auxiliary lanes. The conclusion from these combined analyses using different software tools, is that the Empire Interchange will fail sometime between the Year 2020 and the Year 2040, or a time *beyond* the proposed Capital Improvement Program time period (the next 20 years).

Future Buildout Conditions

As can be seen from Table 1.5, the Buildout p.m. peak hour levels of service for the study area intersections would be at LOS D or better conditions if permissive left turn phasing is implemented. Even so, this analysis shows that there will be link segment operational problems in several locations, which will be discussed later in this section.

When permitted phasing is used at a Diamond Interchange with a wide bridge and multiple lanes in each direction, such as the Empire Interchange, the percentage of angle crashes in the center of the intersection will be notably higher. (source: VTRC Report No. 97-R6).

Permissive or permitted left turn phasing is when left turns are allowed to continue to turn left when there is a gap in traffic in the opposing through movement. This allows the left turns to more efficiently clear the bridge, but with the increased potential for broadside crash accidents. If this permissive phasing is not implemented, severe congestion (LOS E/F) is projected for the Empire Interchange unless some alternative mitigations are implemented (such as a Single Point Urban Interchange, or possibly modern roundabout on the NB Ramps).

Certain situations exist where safety considerations generally preclude the use of permissive left turns. In these cases, left turns should be restricted to the exclusive left turn phase (which significantly reduces capacity). Such situations include:

1. Intersection approaches where crash experience or traffic conflicts criteria are used as the basis for installing separate left turn phasing.

2. Blind intersections where the horizontal or vertical alignment of the road does not allow the left turning driver adequate sight distance to judge whether or not a gap in on-coming traffic is long enough to safely complete his turn.

3. High-speed and/or multilane approaches may make it difficult for left turning drivers to judge gaps in on-coming traffic. Such locations should be evaluated on an individual basis.

4. Unusual geometric or traffic conditions may complicate the driver's task and necessitate the prohibition of permissive left turns. An example of such conditions is an approach where dual left turns are provided.

5. When normal lead-lag phasing is used (due to left turn trapping).

Table 1.5

Intersection Level of Service Analyses Summary for Buildout Year, Mitigation Level 1 (signals, permissive phase)

	Intersection	Type of Control	Critical V/C		Delay		LOS	
			PM	AM	PM	AM	PM	AM
1	Brighton Street at McCourtney Road	Signal	0.62	0.57	20.5	18.8	C	B
2	McCourtney Road at S.R. 20 EB Ramps	Signal	0.42	0.41	6.5	6.3	A	A
3	Mill Street / McCourtney Road	Signal (permissive)	0.91	0.81	18.5	16.5	B	B
4	Mill Street at S.R. 20 WB Ramps	Signal (permissive)	1.44	0.72	46.2	23.1	D	B
5	Empire Street at S.R. 20/49 SB Ramps	Signal (permissive)	0.96	0.59	6.0	3.7	A	A
6	Empire Street at S.R. 20/49 NB Ramps	Signal (permissive)	0.81	0.88	7.9	8.6	A	A

Note: Signals were assumed for each intersection in the buildout scenario, since they are needed as a minimum to mitigate the Year 2020 conditions.

The Empire Interchange has adequate sight distance in either direction along Empire, and typical geometry exists with the exception of dual left turn lanes which can complicate driver vehicle gap judgment.

Although the levels of service for the optimized and coordinated signal system indicate that satisfactory levels of service are possible, the simulated traffic volumes paint another picture. The intersection analysis and level of service rating in intersection analysis software is not sensitive to the traffic operations on the link segments between intersections. The SimTraffic software tool is used in addition to the SynchroPro software, to provide some analysis sensitivity to link segment operations, lane blockages, queuing, etc. The SimTraffic software, which allows visual analysis of the traffic volumes using established flow rate algorithms, can show where left turn pocket overflows will occur, and how this blocking of traffic extends blockages back into adjacent intersections, causing failure. The Buildout volumes had failure on several link segments, even though the intersections themselves can theoretically handle traffic volumes if coordinated properly, and if enough distance existed between intersections. Most link segments in the study area are constrained by short distances between intersections, as well as constraints on road width, especially on Mill Street. These constraints have a negative impact on the ability to mitigate with coordinated signals.

The Empire Interchange ramp intersections were analyzed for the Buildout conditions with permissive phasing programmed into the signal coordination. This helps the levels of service to come out appearing satisfactory, but it is not practically feasible to implement such a signal timing plan on the existing multi-lane intersection approaches due to safety considerations. The result of ordinary protected left signal operations is and LOS E/F condition which can only be mitigated with a modern roundabout or a Single Point Urban Interchange.

FOOTNOTES

(a) Caltrans Counts Comparing a.m. peak hour with p.m. peak hour at various locations along SR 20 in Nevada County

Date and Location	AM volume and Time	PM volume and Time	AM to PM Factor
Feb 98 Wed WB SR 20 @ Idaho Maryland onramp	670 7-8am	1780 5-6pm	0.38
Nov 97 Wed EB SR 20 offramp @ Auburn St.	518 7-8am	458 5-6pm	1.13
Jul 98 Wed EB SR 20 onramp @ Empire St.	586 7-8am	551 5-6pm	1.06
Jul 98 Wed WB SR 20 onramp @ Auburn St.	203 7-8am	443 5-6pm	0.46
TOTALS	**1977**	**3232**	**0.61**

As can be seen from the table above, overall, the pm peak hour volumes are much higher than are the am peak hour volumes. In specific locations where this is not the case, they are still fairly equal. As a result, the analysis of the am peak hour is not anticipated to generate any significant impacts above and beyond those already identified in the pm peak analyses. The 0.61 am to pm factor is taken with a fairly small but representative sample size. To be conservative in our analyses, we used a 0.80 factor for am peak hour volumes (to be derived from pm peak volumes), and we reversed the logical flow patterns.

WORKING PAPER NO. 2

Task 2 Analyses of the Weaving Areas

Overview

There are two sections of freeway in this study which have weaving conflicts due to proximity with on ramp and off ramps. This working paper provides information pertaining to the analysis of the weaving conflict conditions for various existing and future scenarios. In general, the weaving conflicts along the study area freeway segments analyzed do not present a significant level of service challenge for the existing conditions. However, the eastbound section of SR 20 between the Empire Street and Auburn Street ramps is projected to fail in the future Year 2040 and buildout scenarios. The westbound direction of this freeway segment will also experience a deterioration of level of service at a slower rate. The details are contained in the paragraphs that follow.

Introduction

The latest version of the Highway Capacity Manual (HCM) Chapter 4 was used to analyze weaving conditions along the study corridor on sections of S.R. 20 where weaving takes place. The various types of weaves defined in the HCM are shown in Figures 2.1.a, 2.1.b, and 2.1.c below. For this study area, the type of weave indicated in Figure 2.1.a applies because the weave is caused by an on-ramp into an auxiliary lane, and then a fairly quick diverge to an off-ramp (the auxiliary lane ceases).

Weaving is defined as the crossing of two or more traffic streams traveling in the same general direction along a significant length of highway without the aid of traffic control devices. Weaving areas are formed when a merge area is closely followed by a diverge area, or when an on-ramp is closely followed by an off-ramp and the two are joined by an auxiliary lane. Weaving areas require intense lane-changing maneuvers as drivers must access lanes appropriate to their desired exit point. This is especially true in the study area because of the very short weaving areas between ramps, primarily due to design constraints when the Golden Center Freeway and the short freeway section of S.R. 20 towards Brighton was first constructed through the City of Grass Valley. Weaving areas may exist on any type of facility: freeways, multilane highways, two-lane highways (in interchange areas), or arterials.

Figure 2.1.a Type A Weave

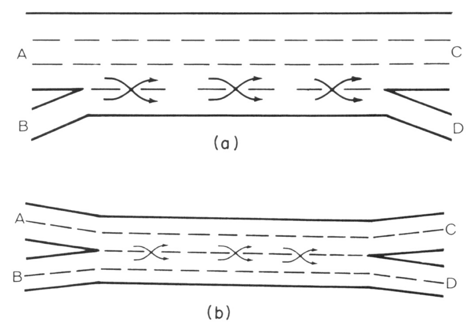


Figure 4-3. Type A weaving areas: (a) ramp-weave/one-sided weave, and (b) major weave.

Figure 2.1.b Type B Weave

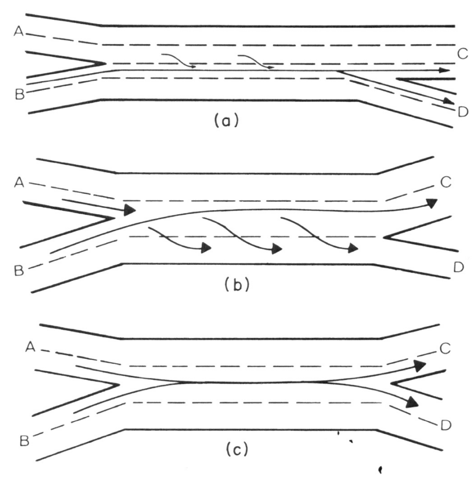


Figure 4-4. Type B weaving areas: (a) major weave with lane balance at exit gore, (b) major weave with merging at entrance gore, and (c) major weave with merging at entrance gore and lane balance at exit gore.

Figure 2.1.c Type C Weave

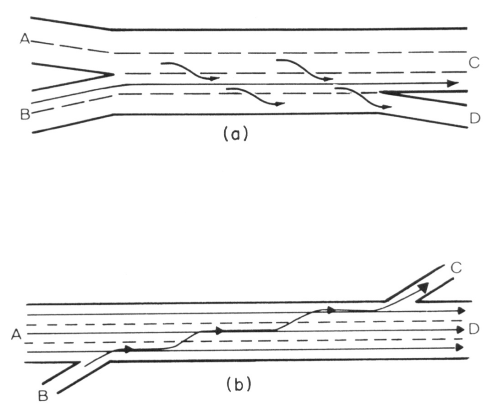


Figure 4-5. Type C weaving areas: (a) major weave without lane balance or merging, and (b) two-sided weave.

Figure 2.1 Freeway Weave Types

Figure 2.2 Study Area Type A Weave Locations 1-4 (shown in yellow)

These weaving areas present special operational problems and design requirements that are addressed by the HCM Chapter 4 methodologies. The HCM Chapter 4 methodology used in this study was developed using research conducted in four widely separated studies: by the Bureau of Public Roads in the early 1960s (published in an appendix to the 1965 HCM, but not used therein); by the Polytechnic University in the early 1970s (1–3); by Leisch in the 1970s (4), and by JHK & Associates in the early 1980s (5).

Existing PM Peak Hour Conditions

The pm peak hour has the highest volumes in the study area overall, and is the critical time period for the freeway operations. Caltrans regularly conducts traffic counts along state highway and freeway systems. The following table documents the most current traffic count data available from Caltrans for SR 20 in the study area.

Table 2.1

Traffic Count Summary for SR 20

Route	Post Mile	Description	Peak Hr	Peak Mo	AADT
20	6.6	PENN VALLEY DRIVE	1400	16000	14200
20	12.16	GRASS VALLEY, MILL STREET	1550	17300	17100
20	12.24	GRASS VALLEY, JCT. RTE. 49	2900	34000	33000
20	12.86	GRASS VALLEY, AUBURN STREET	3750	44000	39500

Source: Caltrans Traffic Operations, 1998 Traffic Volumes

Table 2.2
Weave Section Level Of Service Summaries for PM Peak Hour

	Weave Section	Year 2000	Year 2020	Year 2040	Buildout
1	S.R. 20 Eastbound between McCourtney and Empire ramps	47 mph LOS A	44 mph LOS A	43 mph LOS B	41 mph LOS B
2	S.R. 20 Westbound between Empire SB ramp and Mill Street off ramp	38 mph LOS B	32 mph LOS B	30 mph LOS C	28 mph LOS C
3	S.R. 20 Eastbound between Empire and Auburn Street ramps	44 mph LOS A	39 mph LOS D	37 mph LOS E	32 mph LOS F
4	S.R. 20 Westbound between Auburn Street and Empire Street ramps	39 mph LOS B	35 mph LOS F*	34 mph LOS F*	32 mph LOS F

***Borderline fail based on high volumes.** *This location has a very low weave ratio (0.10), but has a high diverge from SR 20 WB to the offramp (1839 vph). Increasing the weave distance can't help, only reducing volume or providing grade separation.*

From Table 2.1, it can be seen that the existing two-way total peak hour freeway volume on SR 20 segment between its junction with SR 49 and the

Auburn Street ramps is 2,900 vehicles per hour. The directional split on the Golden Center Freeway varies from segment to segment, but the general split of the section above with 2,900 vehicles per hour is 55% (or 1,595 vph) westbound and 45% (or 1,305 vph) eastbound.

The LOS for the four weaving areas in the study area are set forth in Table 2.2 which reports the p.m. peak hour LOS for the weaving sections for the existing Year 2000 conditions, the Year 2020 conditions, the Year 2040 conditions, and the Buildout conditions. The various LOS reported in this table are for unmitigated conditions.

The results of this freeway weaving analyses indicates that traffic operations on the SR 20 freeway north of Empire Street will begin to breakdown into unacceptable conditions by the Year 2020 for the westbound direction of SR 20. Traffic conditions will continue to get worse in all later scenarios (Year 2040 and Buildout), and the eastbound direction will enter into LOS E by 2040 and LOS F by Buildout of Grass Valley's General Plan.

There are potential mitigations for these projected conditions to be discussed later in this report, including widening of the freeway, and building a Grass Valley Bypass west of the City limits.

REFERENCES:

1. Pignataro, L., et al. NCHRP Report 159: Weaving Areas— Design and Analysis. Transportation Research Board, Washington, D.C. (1975).

2. Roess, R.P., et al. Freeway Capacity Analysis Procedures. Final Report, Project No. DOT-FH-11-9336, Polytechnic University, Brooklyn, N.Y. (1978).

3. Roess, R.P. ''Development of Weaving Procedures for the 1985 Highway Capacity Manual.'' Transportation Research Record 1112, Transportation Research Board, Washington, D.C. (1988).

4. Leisch, J. Completion of Procedures for Analysis and Design of Traffic Weaving Areas. Final Report, Vols. 1 and 2, Federal Highway Administration, Washington, D.C. (1983). Updated December 1997 geometry. The additional lane on Leg C would most likely be dropped at some downstream point, because it is not needed to provide for LOS C on that leg.

5. Reilly, W., et al. Weaving Analysis Procedures for the New Highway Capacity Manual. Technical Report, JHK & Associates, Tucson, Ariz. (1983).

WORKING PAPER NO. 3

Task 3 Analyses of Ramp Junctions

The Highway Capacity Manual (HCM) Chapter 5 was used to analyze ramp junction conditions along the S.R. 20 corridor where two ramp junctions with S.R. 49 occur. The various types of merge and diverge sections of freeways defined in the HCM are shown in Figures 3.1.a, 3.1.b, 3.1.c, and 3.1.d below. For this study area, the type of merge and diverge indicated in Figures 3.1.b and 3.1.d apply, because the merge is aided by an auxiliary lane, and the diverge is the end of an auxiliary lane.

Figure 3.1.a Merge Type A

Figure 3.1.b Merge Type B

Figure 3.1.c Diverge Type A

Figure 3.1.d Diverge Type B

Figure 3.1 Freeway Merge / Diverge Types

Figure 3.2 Study Area Merge / Diverge Locations 1-4 (shown in yellow)

A ramp may be described as a length of roadway providing an exclusive connection between two highway facilities. Such is the case with the junction at the Empire Interchange ramp system. SR 20 and SR 49 come together at a grade separation over the Golden Center Freeway. Ramp-freeway junction analysis procedures may be applied to ramp junctions on nonfreeway facilities, such as expressways, multilane highways, and two-lane highways, provided that the junctions involve merging or diverging movements not controlled by traffic signals or stop or yield signs. Such is the case of the S.R. 20 corridor between the Empire Interchange and the Mill Street / McCourtney ramps.

A ramp may consist of up to three geometric elements of interest:

1. The ramp-freeway junction
2. The ramp roadway
3. The ramp-street junction

A ramp-freeway junction is generally designed to permit high-speed merging or diverging to take place with a minimum of disruption to the adjacent freeway traffic stream. The geometric characteristics of ramp-freeway junctions vary. Elements such as the length and type (taper, parallel) of acceleration or deceleration lane, free-flow speed of the ramp in the immediate vicinity of the junction, and sight distances may all influence ramp operations.

Upstream freeway traffic competes for space with entering on-ramp vehicles in merge areas. At off-ramps the basic maneuver is a diverge, that is, a single traffic stream separating into two separate streams. Exiting vehicles must occupy the lane adjacent to the off-ramp, Lane 1 for a right-hand off-ramp. Thus, as the off-ramp is approached, exiting vehicles move right. This movement brings about a redistribution of other freeway vehicles, which move left to avoid the turbulence of the immediate diverge area.

The LOS for the four merge / diverge areas in the study area are set forth in Table 3.1 below. Table 3.1 reports the p.m. peak hour LOS for the weaving sections for the existing Year 2000 conditions, the Year 2020 conditions, and the Buildout conditions. The various LOS reported in this table are for unmitigated conditions.

The freeway to freeway diverge analysis was applied to the ramp systems at the SR 20/49 grade separated interchange where applicable. Satisfactory levels of service will be possible through the Year 2020 if the weaving of traffic is not a factor. However, the weave function of the SR 20 WB ramp at Empire (location #4) will have failure in the weaving operations as discovered in Working Paper #2 of this report.

Table 3.1

Diverge Section Level Of Service Summaries

	Merge / Diverge Section	Year 2000	Year 2020	Year 2040	Buildout
1	S.R. 20 Eastbound between McCourtney Ramps and Empire SB on ramp	48 mph LOS B	48 mph LOS B	47 mph LOS B	45 mph LOS C
2	S.R. 20 Westbound between Empire SB ramp and Mill Street off ramp	*not applicable*	*not applicable*	*not applicable*	*not applicable*
3	S.R. 20 Eastbound between Empire and Auburn Street ramps	*not applicable*	*not applicable*	*not applicable*	*not applicable*
4	S.R. 20 Westbound btwn Auburn Street and Empire Street ramps	49 mph LOS A	47 mph LOS D	44 mph LOS E	38 mph LOS F

The results of these analyses, indicate that the merge/diverge freeway operations for the westbound direction of SR 20 north of Empire Street will become unacceptable (LOS E conditions) by the Year 2040, and fail at Buildout of Grass Valley's General Plan.

REFERENCES

1. Pignataro, L., et al. NCHRP Report 159: Weaving Areas— Design and Analysis. Transportation Research Board, Washington, D.C. (1975).
2. Roess, R.P., et al. Freeway Capacity Analysis Procedures. Final Report, Project No. DOT-FH-11-9336, Polytechnic University, Brooklyn, N.Y. (1978).
3. Roess, R.P. ''Development of Weaving Procedures for the 1985 Highway Capacity Manual.'' Transportation Research Record 1112, Transportation Research Board, Washington, D.C. (1988).
4. Leisch, J. Completion of Procedures for Analysis and Design of Traffic Weaving Areas. Final Report, Vols. 1 and 2, Federal Highway Administration, Washington, D.C. (1983). Updated December 1997 geometry. The additional lane on Leg C would most likely be dropped at some downstream point, because it is not needed to provide for LOS C on that leg.
5. Reilly, W., et al. Weaving Analysis Procedures for the New Highway Capacity Manual. Technical Report, JHK & Associates, Tucson, Ariz. (1983).

WORKING PAPER NO. 4

Task 4 Modeling, Analyses of Existing and Future Conditions

The Nevada County Transportation Commission's MINUTP traffic model was utilized for this study to provide traffic projections for future year scenarios. The Year 2015 model was updated using the latest information developed in the Grass Valley General Plan Update, and this was incorporated into a new NCTC Year 2020 conditions model. This Year 2020 model was used to develop a variety of future year traffic projections for the study area. The traffic projections included turning movements at the critical study intersections, as well as street segment and freeway segment volumes for the p.m. peak hour. The MINUTP model was also updated for the Year 2040 and the Buildout conditions (2050+). The Year 2040 model was generated from the NCTC's Year 2020 model, however, we utilized the Buildout MINUTP model developed in the Grass Valley General Plan Update, having received this file from the City. We modified the internal/external parameters for balancing productions and attractions so as to maximize the trip generation assigned to the street network. The internal attraction trip generation in the Buildout MINUTP model was much higher than the productions internal totals, so much of the attraction trip generation needed to be assigned external to the County in order to achieve trip anticipated generation estimations for the future growth. This significant increase in trip generation over the Year 2020 conditions led to some negative traffic impacts within the study area that require mitigations. These impacts and mitigations are discussed in detail in Working Papers No. 1, 2, and 3.

In addition to the future year forecasts developed using the NCTC's MINUTP updated traffic model for the Year 2020, 2040, and Buildout conditions, we also developed Synchro Pro and SimTraffic files for these same future years, as well as for existing conditions. The Synchro Pro software enables the analysis of signalized intersections, and with the professional package, simulations of the traffic flows can be viewed and analyzed. The SimTraffic software actually simulates the traffic flows and turning movements at each of the study intersections and street segments. Even the freeway volumes and ramp merges and weaving are modeled in this software. The results of our various analyses using the NCTC MINUTP model projections as well as the Synchro Pro and SimTraffic software models can be seen in the various working papers developed in this study by clicking on the link below.

A complete listing of all traffic model files can be seen and reviewed (some files require certain software applications to run) by clicking on the Model Files link at the www.prismworld.com web site.

WORKING PAPER NO. 5

Task 5 Roundabout Feasibility Analyses

Introduction

"Modern Roundabouts" are gaining popularity in the United States due to their simplicity and lower cost as a solution to traffic calming, driver safety, and high capacity. In this study several locations are being recommended for conversion to a modern roundabout as an alternative to signalization. In some cases the turning movements at an intersection or the unique geometry of an intersection (often having skewed approaches) need an improvement other than signalization, because in some cases, a signal installation can't provide the capacity or traffic operations adequately. For example, when wide roads with several approach lanes at an intersection is not possible due to physical constraints, and where street segments are short and adequate storage for vehicle queues in left turn pockets is not possible, then an alternative to signalization becomes necessary. In some of these cases, a modern roundabout can help.

The study area includes the freeway section of SR 20 and Empire Street just east of the NB freeway ramp intersection. It also includes McCourtney Road from Brighton Road to Mill Street, and Mill Street from McCourtney Road to just beyond the SR 20 WB Ramps at Mill Street. Some of the intersections within the study area are constrained by physical boundaries and topography, as well as existing adjacent roadways, which prevent any significant widening or realignment of roadway segments. The intersections themselves have been examined for potential modifications in both signalized options, as well as modern roundabout options.

Modern Roundabouts have been successfully installed at several locations within the United States. One such installation in Santa Barbara is particularly worthy of note, due to its unique design, which brings together five intersection legs.

Figure 5.1 shows the installation of a modern roundabout at one side of a freeway interchange, to bring together in some order, five legs of an intersection into an oval shaped modern roundabout (with yield on entry).

Figure 5.1 Modern Roundabout Installation at SR 101 and Milpas St. in Santa Barbara, CA

(Photo source: 101 / MILPAS STREET INTERCHANGE PROJECT)

As can be seen from Figure 5.1, the intersection is easy to visually comprehend, and the driving pattern is obvious: right turns only, and yield on entry.

The signage and pavement markings make this intersection alternative safe and easy to navigate.

A plan view animation of this intersection has been prepared (shown at left), and can be seen at http://www.milpasroundabout.com/automobile.html. This animation illustrates typical vehicle movement through the 5 leg modern roundabout intersection shown in Figure 5.1. Flash Player (Macromedia) is required to view the animation.

ANALYSIS

Mill Street Corridor

The McCourtney / Mill Street intersection is a hub for two busy street corridors both now and especially in the future. Failure is predicted for this intersection which is fairly close to the SR 20 ramp intersections. Traffic operations will break down in the future, even with coordinated signalized mitigation along the surface street traffic corridors of Mill Street and McCourtney Road. Year 2020 traffic projections for the Mill Street corridor were mitigated with a coordinated signal system, and still LOS F conditions would exist at the Mill Street / McCourtney intersection. One of the primary reasons that traffic operations will break down at Mill St / McCourtney Road is because of the high left turn conflicts, which leads to high delays in getting traffic through this intersection. It is also not feasible to sufficiently widen the intersection or Mill Street to accommodate the multi-lane approaches that would be needed to increase throughput capacity.

With the current configuration, traffic is obliged to "take turns" with a phase of the signal cycle. This stop and go movement loses speed, wastes some capacity, and can lead to blocked adjacent intersections from traffic back-ups from this intersection. This is especially true because of the short distance of the Mill Street segment between McCourtney Road and the SR 20 WB Ramps intersection (300 feet, which means a single lane left turn pocket length of 125 feet max). This 125-foot left turn pocket cannot hold the projected volumes even in the short-term future, let alone the buildout volumes. What is needed is a system that does not depend on storage lengths for left turn movements, but which offers a clear path of travel for all traffic. The modern roundabout can facilitate such a system of vehicular movement, and do so with narrow roads connecting intersections (a condition ideal to Mill Street).

Figure 5.2 was created in AutoCAD and depicts a system of two modern roundabouts for the Mill Street corridor from McCourtney Road to the SR 20 WB Ramp intersection. Full engineering D size drawings of this figure are available for download in AutoCAD Whip formats, as well as Adobe PDF formats on the www.prismworld.com web site.

This system of modern roundabouts it needed at this location to enable capacity enhancements in the system without major widening of the roadways. Even if major widening of the roadways was feasible in the area, which it is not, the capacity could not be significantly improved due to the short street segment lengths which directly affects left turn pocket lengths.

Short street segments pose a traffic operations challenge to the signalized intersections at each end of the segment. Storage lengths of left turn pockets are very short, and the "jockeying" of traffic movements getting into these short lanes can cause through lane blockage, etc.. The intersections of McKnight Way and the SR 49 freeway ramp intersections are a good example of how this will present a problem in the near future for signalized traffic operations.

The intersections of McCourtney Road and Mill Street, as well as Mill Street and the SR 20 WB Ramps, have been analyzed for existing and future conditions (see Working Paper 1). The Mill Street intersections will fail, even with signalized intersections "coordinated" together. We utilized the Synchro Pro and SimTraffic simulation software to test various configurations for signalization along the corridor. The various software tools bear out the conclusion that signals are not the answer unless major widening was possible. Environmentally, it makes no sense to widen Mill Street to a six-lane arterial tapering back down to two lanes just north of the SR 20 overpass. The needed distance does not exist before the Mill Street corridor is constrained by narrow road widths and existing buildings on each side of the road. The traffic operations analysis conducted showed that traffic would back up into adjacent intersections, leading to a break down of operations.

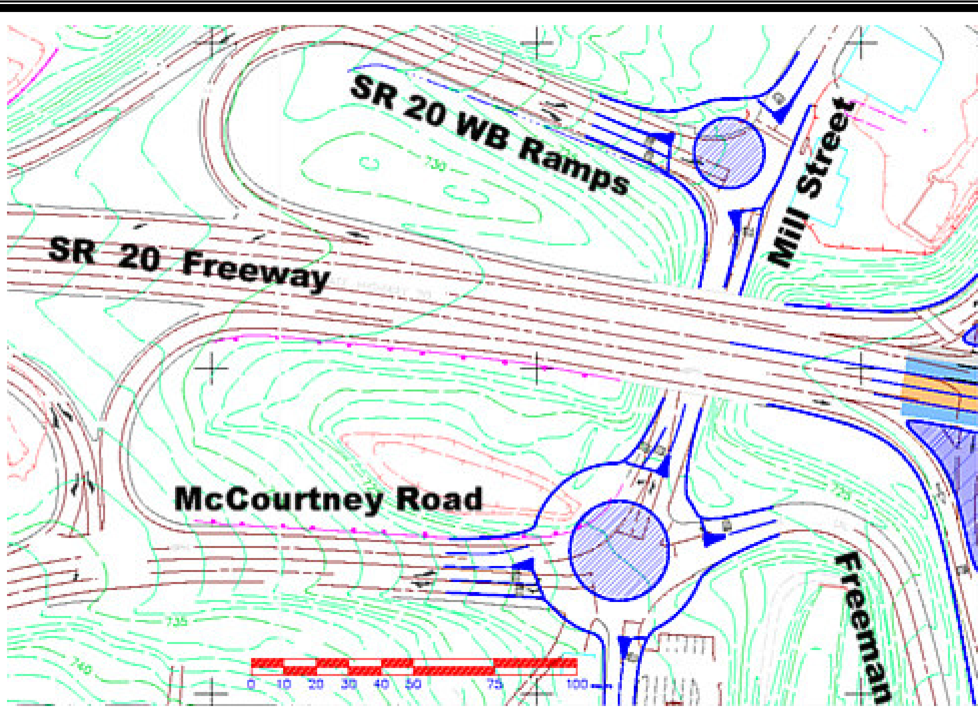


Figure 5.2 Mill Street Corridor Modern Roundabouts

The reason traffic operations will break down is primarily due to the need for numerous lanes at each leg of the intersection, dual left turns, two receiving lanes, two throughs, right turn pockets, etc., all of which will not fit in the area available. Because these widening mitigations are not feasible or desirable, traffic backs up in long queues, which reach adjacent intersections (such as the SR 20 EB Ramps at McCourtney Road). The Mill Street segment below SR 20 is completely stopped down with congestion. For these reasons, the modern roundabout mitigation was explored as an option.

The modern roundabout fits within the existing right of way, and for the most part, these roundabouts utilize the existing lane geometry for intersection approaches (one or two lane entries). Geometrically, the improvements fit within the immediate intersection area, with some widening at intersection corners to accommodate the circular shape of the roundabout. Figure 5.2 shows these two modern roundabouts superimposed onto the existing street system and curb lines so that it can be seen by inspection how the improvements will impact the existing conditions. For additional detail, and the ability to pan and zoom in close on any part of the graphic, and print with high resolution, Figure 5.2 has been prepared in an Adobe PDF file format available at the following link: Figure 5.2 PDF format.

A Synchro Pro model was constructed for the modern roundabout mitigations at Mill Street / McCourtney and at the SR 20 WB Ramps. The model was transferred to the SimTraffic animation software to inspect the results for traffic operations effectiveness, and the modern roundabouts were found to be a viable solution for Year 2020 traffic, Year 2040 traffic, and even the Buildout level traffic volumes in the future. The model shows the traffic flowing through the intersections smoothly, and because there is no "red time" mandated by a signal, traffic is allowed to flow slowly like water into and out of each intersection. Travel speeds are typically 15 mph in average through an intersection modern roundabout, creating a "traffic calming" effect and safer conditions as far as impact crash accidents are concerned. An Flash Animation file has been prepared to illustrate traffic flows at the proposed modern roundabout locations. It can be found on www.prismworld.com under the pages for this study.

Empire / SR 20 Corridor

For the most part, SR 20 has ample throughput capacity in its four freeway lanes within the study area to handle Year 2020 traffic flows if merging and weaving were not an issue. The weaving analyses indicated that there would be a problem (LOS F) before the Year 2020 scenario for the westbound direction of SR 20 just north of Empire Street. Conditions worsen considerably by the Year 2040 (LOS E or F in both directions) when mainline capacity is taxed despite the presence of an existing auxiliary lane for the east and westbound directions. The weave is significant enough to affect the speed of the mainline freeway operations (slowed to 34 mph).

SR 20 west of the study area may need further analysis to determine if buildout volumes can be accommodated on the two-lane highway sections. Signalized solutions were investigated for the Empire / SR 20 corridor at the freeway ramp intersections of SR 49 and SR 20. If permissive phasing is allowed, it appears that enough traffic can move through these intersections, but with a much greater risk of accidents (see Working Paper 1 and 6 for more discussion on these alternatives). If a modern roundabout is constructed on the corridor at the intersection of Empire Street and the SR 49 NB offramp, it appears that this potential solution could produce satisfactory traffic operations for the Empire Interchange NB ramp intersection. Traffic calming would take place naturally due to the slowed speeds that are to be expected in a modern roundabout, which has yield on entry. The dominant traffic movement through this intersection is by far the Empire Street EB left turn movement onto the SR 20 freeway ramp going north. This single movement of traffic accounts for nearly half of all traffic traveling through the intersection. Considering that it is only one of five possible movements, this is a significant majority. This heavy stream of traffic could be accommodated well through a modern roundabout at this location. An illustration of how this may be possible is given in Figure 5.3. This figure is available in full D size Engineering AutoCAD Whip drawing format, as well as PDF formats on the www.prismworld.com web site.

Figure 5.3 Empire Street Modern Roundabout

The modern roundabout shown in Figure 5.3 will accommodate the projected traffic flows from the buildout projections in the Grass Valley General Plan Buildout. The two lanes of travel entering the NB Ramp will most likely have an impact on the freeway operations of SR 20 eastbound where the NB onramp merges with the freeway. This is primarily due to the Golden Center Freeway being over-capacity in the future with projected traffic volumes of 4,500 vph for two lanes on a freeway. The westbound direction is heaviest during the pm peak hour, with a volume of 4900 just north of Auburn Street. The Year 2040 traffic projections for the Golden Center Freeway were approximately 95% of the Grass Valley General Plan Buildout projections, and would still be near LOS F capacity. These volumes will mean that during peak time periods there will likely be stop and go traffic on the freeway, sometime just before the Year 2040, which could lead to back-ups onto the Empire Bridge. A modern roundabout at the Empire Street SR 20/49 NB Ramp intersection will slow speeds and meter freeway-bound platoon traffic better than would a signal installation at this intersection. The downside to the modern roundabout installation at this location is the impact to the westbound approach of Empire Street. The traffic for this approach is delayed significantly, and more especially as the freeway ramp traffic is slowed or backed up into the intersection.

One solution to the impacts projected for the SR 20 / 49 Freeway in the study area is to build additional freeway lanes on SR 20 west of Brighton, and create a new interchange with the previously studied "Western Bypass" for the City of Grass Valley. If this bypass is constructed, and interfaced with SR 20, then the Golden Center Freeway could be relieved slightly of over-capacity volumes in the future buildout conditions. There is not a local mitigation on the SR 20 corridor in the study area that can easily mitigate the over-capacity freeway congestion that will occur on SR 20 north of Empire Street. The capacity problem extends far north of Auburn Street and to the existing bridge structures over the Colfax Highway area in Grass Valley. It appears that only a new parallel facility west of the City, or a significant reduction/revision in land use densities for the Grass Valley General Plan can help relieve the situation.

Cost Estimates

A partial listing of the various cost factors used in developing preliminary cost estimates in this study are given in Tables 5.1, 5.2, and 5.3 which follow. Each table summarizes the various components that went into each cost estimate for construction of the three modern roundabouts depicted in Figures 5.2 and 5.3.

The cost estimate factors were received from Caltrans District 3, and were applied to the construction cost estimates for this project, which is within the jurisdiction of District 3. In order to compute the quantities of new construction, earth moved, etc., we utilized the AutoCAD drawings which are drawn to scale, and which also contain topographical information. We were able to calculate the “exact” areas of new bridge, new pavement, etc. using the features within the AutoCAD software using MASSPROP on the regions of pavement area selected.

The values of area shown in the tables that follow are based on the areas drawn in the figure, and are only applicable to the design shown in each improvement alternative. As far as we were able to determine from field investigations and general on-site observations, the planning level designs depicted in this study are possible to construct. The cost factors supplied by Caltrans are conservatively high, and account for various unknown and hidden costs and contingencies.

By way of example, Table 5.1 itemizes the costs associated with construction of a large modern roundabout at the NB Ramps of the Empire Interchange. Certain earthwork and construction would need to be accomplished at each of the four corners of the existing intersection before construction of the roundabout is possible. For example, shown on the table, at the NW Corner there would be 258 m2 of asphalt concrete pavement to be removed, and landscaping installed. On the NE Corner there would be 777 m2 of surface area for new construction. New dirt would need to be brought in for fill (777x1.5 m3 = 1170 m3) at a cost of $18.1k, and some new sub base aggregate would need to be installed at a cost of approximately $16k (slightly more than half of the total cost of $30.2k). In addition, new asphalt concrete (ac) would need to be installed on top of the entire surface area of the project as shown in Figure 5.3, a total area of 6,100 m2, which calculates out to 1,360 tonns of ac as shown in the table. Other items such as drainage, guardrails, etc. were entered in as lump sum cost items using typical costs for similar size projects.

Table 5.1
Caltrans Construction Cost Factors and Summary
for Empire Interchange Modern Roundabout (see Figure 5.3)

Construction Activity	Units of Measure	Cost per Unit*	Units	Cost Estimate
1. Earthwork Construction	NW Corner: 258 m2 to be removed NE Corner: 777 m2 new install, incl. Fill SE Corner: 723 m2 new install, incl. Excavation SW Corner: 222 m2 to be removed			
*Roadway Excavation	Cubic Meter	$13.00	1080 m3 (723x1.5m3*)	$14.0k
*Imported Borrow	Cubic Meter	$15.50	1170 m3 (777x1.5m3*)	$18.1k
*Clearing & Grubbing	Lump Sum	$10,000	N/A	$10k
2. Pavement Structural Section	6100 m2 total area of new ac pavement, including bridge and NB freeway ramps, 4" depth.			
*Asphalt Concrete (Type A)	Tonn	$44.00	1360 (6100m2 x 2 Tonn/m3 x 1/9)	$60k
*Aggregate Base	Cubic Meter	$36.00	840 (777+723)m2 x (560/1000)m**	$30.2k
*25 mm OGAC***	Tonn	$46.00	N/A	N/A
3. Drainage				
*Storm Drains	Lump Sum	$30,000	N/A	$30k
*Project Drains	Lump Sum	$10,000	N/A	$10k
4. Specialty Items				
*Guardrails, landscaping	Lump Sum	$250,000	N/A	$250k
5. Traffic and Minor Items, Mobilization				
*Delineation, signs, signals, etc.	Lump Sum	$400,000	N/A	$200k
6. Roadway Additions				
*Supplemental Work	5% of items 1-5	$(0.05) x (1-5)	$822.3k	$41.1k
*Contingencies	25% of items 1-6	$(0.25) x (1-6)	$863.4k	$215.9k
TOTAL				**$880,000**

Cost estimate factors source: Caltrans District 3
Note: 3 meter change in elevation for cut/fill areas, assumed 1.5 m depth avg. on slopes.
***Source: Table 607.2, Caltrans Design Manual, assume TI=10.5-12 for heavy trucks.*
****Open Graded Asphalt Concrete (OGAC), also known as an "open graded friction course"*

Table 5.2
Caltrans Construction Cost Factors and Summary
for McCourtney/Mill St Modern Roundabout (see Figure 5.2)

Construction Activity	Units of Measure	Cost per Unit*	Units	Cost Estimate
1. Earthwork Construction	NW Corner: 585 m2 new install, incl. Fill NE Corner: 95 m2 new install SE Corner: 152 m2 new install, incl. Fill SW Corner: 62 m2 new install, incl. excavation			
*Roadway Excavation	Cubic Meter	$13.00	76 m3 (152x0.5m3*)	$1.0k
*Imported Borrow	Cubic Meter	$15.50	737 m3(585+152) m2 x 1.0m*	$11.4k
*Clearing & Grubbing	Lump Sum	$10,000	N/A	$10k
2. Pavement Structural Section	2890 m2 total area of new ac pavement, 4" depth.			
*Asphalt Concrete (Type A)	Tonn	$44.00	642 (2890m2 x 2 Tonn/m3 x 1/9)	$28.3k
*Aggregate Base	Cubic Meter	$36.00	501 (585+95+152+62)m2 x (560/1000)m	$18.0k
*25 mm OGAC***	Tonn	$46.00	N/A	N/A
3. Drainage				
*Storm Drains	Lump Sum	$30,000	N/A	$30k
*Project Drains	Lump Sum	$10,000	N/A	$10k
4. Specialty Items				
*Guardrails, landscaping	Lump Sum	$100,000	N/A	$100k
5. Traffic and Minor Items, Mobilization				
*Delineation, signs, signals, etc.	Lump Sum	$75,000	N/A	$75k
6. Roadway Additions				
*Supplemental Work	5% of items 1-5	$(0.05) x (1-5)	$283.7k	$14.2k
*Contingencies	25% of items 1-6	$(0.25) x (1-6)	$297.9k	$74.5k
TOTAL				**$372,400**

Cost estimate factors source: Caltrans District 3
Note: 2 meter change in elevation max for cut/fill areas, used 1.0 m depth avg. on slopes.
***Source: Table 607.2, Caltrans Design Manual, assume TI=10.5-12 for heavy trucks.*
****Open Graded Asphalt Concrete (OGAC), also known as an "open graded friction course"*

Table 5.3
Caltrans Construction Cost Factors and Summary
for Mill St/SR 20 WB Ramps Modern Roundabout (see Figure 5.2)

Construction Activity	Units of Measure	Cost per Unit*	Units	Cost Estimate
1. Earthwork Construction	NW Corner: 284 m2 new install, incl. Fill SW Corner: 90 m2 new install, incl. excavation			
*Roadway Excavation	Cubic Meter	$13.00	90 m3 (90x1.0m3*)	$1.2k
*Imported Borrow	Cubic Meter	$15.50	284 m3 (284x1.0m3*)	$4.4k
*Clearing & Grubbing	Lump Sum	$5,000	N/A	$5.0k
2. Pavement Structural Section	1805 m2 total area of new ac pavement, 4" depth.			
*Asphalt Concrete (Type A)	Tonn	$44.00	401 (1805m2 x 2 Tonn/m3 x 1/9)	$17.7k
*Aggregate Base	Cubic Meter	$36.00	210 (284+90)m2 x (560/1000)m**	$7.6k
*25 mm OGAC***	Tonn	$46.00	N/A	N/A
3. Drainage				
*Storm Drains	Lump Sum	$30,000	N/A	$30k
*Project Drains	Lump Sum	$10,000	N/A	$10k
4. Specialty Items				
*Guardrails, landscaping	Lump Sum	$50,000	N/A	$50k
5. Traffic and Minor Items, Mobilization				
*Delineation, signs, signals, etc.	Lump Sum	$50,000	N/A	$50k
6. Roadway Additions				
*Supplemental Work	5% of items 1-5	$(0.05) x (1-5)	$175.9k	$8.8k
*Contingencies	25% of items 1-6	$(0.25) x (1-6)	$184.7k	$46.2k
TOTAL				**$230,900**

Cost estimate factors source: Caltrans District 3
Note: 1-2 meter change in elevation for cut/fill, assumed 1.0 m depth avg. on slopes.
***Source: Table 607.2, Caltrans Design Manual, assume TI=10.5-12 for heavy trucks.*
****Open Graded Asphalt Concrete (OGAC), also known as an "open graded friction course"*

WORKING PAPER NO. 6

Task 6 Identify Future Improvement Alternatives

Overview

The analysis summaries of Working Papers 1, 2, 3, and 4 indicate traffic congestion trouble ahead for the study area freeway and surface street road network. This working paper discusses various traditional improvement alternatives including widening of roads, bridge construction, signal timing and coordination plans, as well as new roadways constructed (such as the Grass Valley Western Bypass).

The Empire Interchange of SR 20 and SR 49 performs well at the current time (Year 2000), and on into the Year 2020. In the long term future however (year 2040 and beyond), there are improvements that would need to be made to the interchange in order to adequately move traffic. The Empire Street bridge over the Golden Center Freeway is not configured properly to handle future Grass Valley General Plan Buildout projections, or the NCTC Year 2040 projections at acceptable levels of service, given the complex traffic dynamics that do now exist in this study area. The traffic operations and level of service are a function of the effectiveness of intersection signals and coordination (or roundabouts), lane blockages, backing or queuing of traffic flows, freeway merging conflicts for ramps (auxiliary lanes) and mainline freeway, as well as freeway mainline capacity.

Several alternatives were investigated along the corridor including signal timing and phasing alternatives, roundabout construction (see Working Paper No. 5), as well as traditional widening and bridge structures construction. The Single Point Urban Interchange was conceptually designed for the existing Empire Interchange, and analyzed for future traffic, and found to be an acceptable, albeit expensive improvement alternative.

Single Point Urban Interchange, A History

A Single Point Urban Interchange (SPUI) is a type of highway interchange, and is also known as a Single Point Diamond, or Greiner's Urban Interchange. It is like a diamond but with a single traffic light in the middle, which allows for concurrent left turns. The freeway can go over or under the crossing arterial roadway. There are typically three signal cycle phases (left turns, thru movements, left turns), but when frontage roads exist, delay goes up significantly because of the addition of a fourth phase.

This view of a new SPUI in Salt Lake City, Utah is taken from the top of the northbound I-15 ramp looking northwest across 6th North. For drivers who have never encountered a SPUI, the configuration can be somewhat daunting. All of the left-turns are made across a single point, resulting in a somewhat confusing pattern of guiding stripes criss-crossing the intersection. The centerline of the freeway below is exactly aligned with the signal installation.
(Photo source: Dan Moraseski's SPUI list at http://members.xoom.com/spui/spui/index.html.)

Single Point Urban Interchange, a three dimensional example, cross street above.
(Graphic source: UDOT, I-15 Reconstruction Project)

A "Plan View" of signal operations at a single point in center of bridge (or in this case, on street below bridge)

Figure 6.1 Single Point Urban Interchange, an Example

A SPUI requires less right-of-way than a standard diamond or parclo. The first SPUI in the US was built in Clearwater, FL on US 19 at FL 60 by Greiner

Engineering of Tampa, FL. on February 25, 1974. The second SPUI in the US opened on September 9, 1975 on I-74 at 7th Av in Moline, IL. The idea of a SPUI was conceived by Caltrans in 1960 when they proposed an "inside-left turn" interchange for Palo Alto, CA. More information on SPUI's can be found in the book *Single Point Urban Interchange Design and Operations Analysis by the Transportation Research Board*.

The construction costs for a SPUI are typically very high due to the additional bridge structure that is required for the on and off ramps to traverse a circular arc path towards the center of the main intersection. It is not unusual for a SPUI to cost between $25 and $30 million dollars, primarily due to the complexity of the bridge structures and tightly spaced vertical ramp walls. Some cost savings for the Empire Interchange may be possible given the ideal topography and existing vertical ramp walls at the site, as well as the existing extra-wide bridge structure.

Figure 6.1 shows the traffic flow patterns that exist at a SPUI. Note that the opposing left turn movements at the single point intersection are allowed to flow together during the same signal phase, first the left turn movements off of the freeway ramps, and then the left turn movements onto the freeway ramps (two phases of signal time). The through movements on the arterial are on a separate phase of the signal cycle, similar to a conventional signalized intersection. There are a total of three signal cycle phases. This fewer-than-normal number of signal cycle phases provides for increased efficiency and less lost signal green time.

The actual photograph of a SPUI at the top of Figure 6.1 shows how large the intersection actually is, or rather, the travel path may be long and somewhat daunting to the driver unfamiliar with the intersection. The SPUI is unique in that it contains one signalized intersection through which all four left-turn and through movements operate on the local road, but its large, uncontrolled conflict area raises some concerns about the safety of motorists who travel through it. Pedestrians are not easily accommodated with a SPUI design, due to the large intersections and corresponding longer walking distances (which takes up much signal phasing time). Vehicles are obliged to wait longer while a pedestrian traverses a longer distance across travel lanes. For this reason, a SPUI should not be seriously considered if there is significant pedestrian traffic through the main intersection. From what we can tell, the Empire Interchange location with the Golden Center Freeway does not now have any appreciable pedestrian traffic, nor is any projected for horizon planning years.

Studies have been completed which show that a SPUI does not pose any additional accident potential over the traditional Diamond Interchange. (source: VTRC Report No. 97-R6)

One of the advantages of a SPUI is the tight spacing that is possible in a non-cloverleaf freeway interchange, as well as the more efficient traffic operations that are made possible within a single intersection (versus two closely spaced intersections). The so-called "tight diamond" interchanges common on the Golden Center Freeway (with the exception of the Brunswick Interchange which is a partial clover-leaf design) have or will have operational challenges because of the closely spaced intersections of the cross-street bridge structure and the freeway on and off ramps. These intersections are typically between two and three hundred feet apart, which does not allow for significant stacking or storage distances in the left turn movements along the bridge structure. There is a limited capacity to the "tight diamond" interchange if opposing offramp left turns are significant.

Single Point Urban Interchange, a CALTRANS Perspective

Caltrans has recently developed guidelines for the installation of a SPUI, and has circulated this information in a Memorandum to all District Directors from Robert L. Buckley, Program Manager, Design and Local Programs, Caltrans. The memo, dated March 24, 2000, documents various design criteria for SPUI's. Several key points are highlighted in this section. Reference is made to the memorandum for additional details. The Caltrans Design Manual and Traffic Manual are to be used in all cases for road design, but several exceptions are highlighted in the following bullet points.

- The local street alignment shall have adequate decision sight distance through the SPUI intersection (Empire Street has adequate site distance in both directions)
- The size of the SPUI intersection shall not exceed 60 meters if on a vertical crest, and 70 meters if on a sag (this is due to "All Red" signal time considerations, as red time can range from 3.5 to 7.5 seconds!).
- Skew angle of local street should not exceed 15 degrees. 30 deg. max.
- Horizontal curving of local street is undesirable (due to lane alignments)
- Off-ramps should have 1.5x stopping sight distance.
- The "middle diamond" island should be raised, and at least 3.0 m wide.
- Lane widths for left turn lanes should be a minimum of 4.2 meters.
- Where compound curves are used, the smaller curve radius should be at least one half of the larger curve radius (as close as possible).
- Bicycles are difficult to accommodate without disrupting operations of a SPUI. A separate bicycle facility should be considered. The same is true for pedestrians.
- SPUI's with frontage roads are to be avoided.
- Proper design speed of the local street is to be verified by Project Development Coordinator and Traffic Liaison.

- The SPUI should only be selected as a preferred alternative if it warrants the same due to traffic considerations. It should not be selected because it is considered "state of the art," "innovative" or will be a "gateway" to the community.

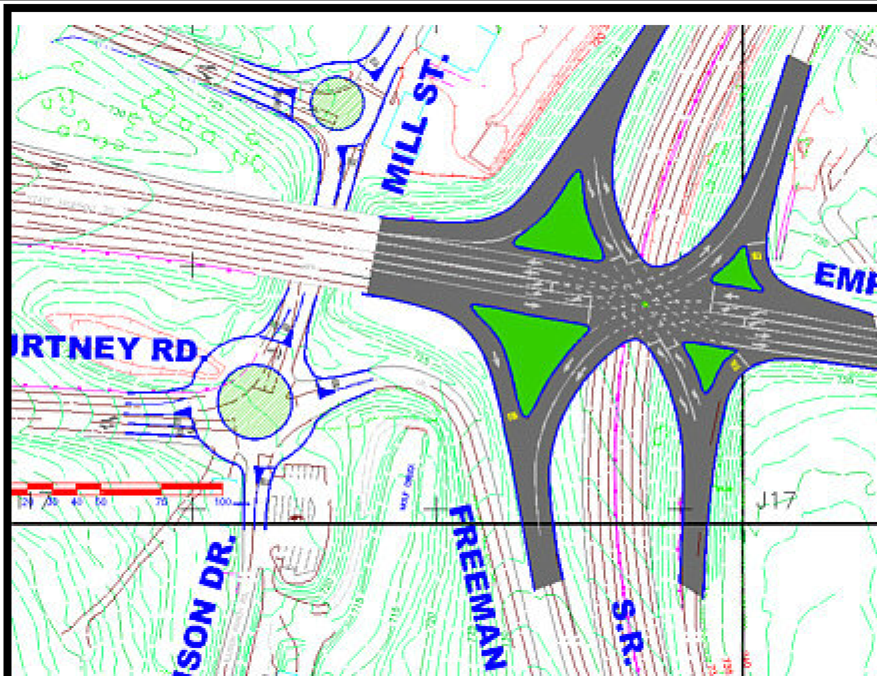
Based on these additional inputs from Caltrans, it is apparent that additional guidelines were necessary to prevent the installation of a SPUI under inappropriate conditions (such as when a community wants a "state of the art" solution or a "gateway" improvement. The various criteria listed above have been evaluated against the potential of installing a SPUI at the Empire Interchange. The Empire Interchange is an ideal location for the design of a SPUI, because the local street (bridge) is perpendicular with the freeway underpass, and there are no vertical or horizontal curves for the SPUI intersection. The only negative for this alternative is its relative cost and the impact it would have to bicycles and pedestrians (or the impact the bicycles and pedestrians may have on the operations of the SPUI intersection during peak time periods).

Empire Interchange Location

The Single Point Urban Interchange (SPUI) has been investigated as a future mitigation for the Empire Interchange location. Figure 6.2 has been prepared which illustrates this improvement alternative at the Empire Interchange location.

Several analyses were conducted with state of the art simulation and animation traffic operations software. We programmed the future buildout volumes into the Synchro Pro model, and used the SimTraffic software to verify traffic movement and vehicle queues. The SPUI alternative moves traffic through the single intersection at acceptable levels of service, and would work for this location. The cost estimate for the SPUI improvements is $4,600,000 (see cost estimate calculation below).

The location is favorable for installation of such a structure as well, with much of the structure already built. The AutoCAD 2000 software was used to superimpose a potential structure onto the existing street system to examine the impacts of construction onto the local landscape. Using AutoCAD files received from the City of Grass Valley we drafted a SPUI configuration that would work for this location. The software was used to calculate the areas of new structure, as well as the area of new pavement (4" overlay ac).



A full size detailed AutoCAD WHIP! file of this SPUI alternative, complete with zoom, pan, and layer control (click right mouse button) is available on the web site version of this document.

In addition, a detailed Acrobat PDF file of this SPUI alternative is available at:

www.prismworld.com

Figure 6.2 Single Point Urban Interchange at Empire Interchange
(Graphics source: PRISM Engineering)

Figure 6.1 illustrates a three dimensional view of a SPUI similar in configuration to what is possible on the SR 20/49 junction at the Empire Interchange. It also demonstrates the traffic operations and traffic flow patterns typical with a SPUI. All traffic is guided to the center of the bridge structure crossing the freeway (such as with the Empire Interchange bridge), or to an arterial surface street intersection below the bridge structure carrying the freeway traffic (as shown in Figure 6.1). The intersection signal operation is typically set for a three phase operation:

1. Off-ramp left turn movements
2. On-ramp left turn movements
3. Arterial local street through movements

A SPUI constructed in place of and using parts of the existing Empire Interchange was analyzed with buildout level traffic forecast volumes, and found to work at a satisfactory traffic operations solution. Traffic would flow nicely through the SPUI bridge intersection along the Empire Street / SR 20 corridor. The SynchroPro traffic operations software package was used to test future volumes. The SimTraffic animation software was also used to verify traffic flows and operations for the lane geometry assumed at this location. From our analysis, it appears that LOS C or better conditions are possible, with the exception of poor freeway operations due to over-capacity projections.

Freeway Operations and Future Street Network

The SR 20 Golden Center Freeway is projected to be over capacity with Year 2040 and Buildout traffic volumes in the future. When a freeway is over capacity, the result is usually failure, and stop and go traffic results, a common experience in urbanized metropolitan cities. Because of projected over-capacity conditions on the Golden Center Freeway, the mainline operations are projected to be in trouble, despite any improvements to the Empire Interchange, the SR 20 corridor, or local surface streets within the study area. It is a matter of a need for additional roadways to carry traffic into and out of the urban area. Figure 6.3 shows the street network assumed for the future analysis.

A detailed PDF file of MINUTP street network viewed in VIPER can be found on:

prismworld.com

Figure 6.3 Future Street Network in Study Area

The street network assumed in this analysis is the same that was assumed in the Grass Valley General Plan Update (GVGPU) recently completed by the City. In this future street network there are new roadways constructed which essentially connect McCourtney Road (at its intersection with Brighton Road) with SR 49 near Crestview Road. There was not any significant improvement to the SR 49 / Crestview intersection discussed in that study, but the traffic volumes projected to use the new road are significant, and are in the range of 1,000 - 1,500 vehicles per hour (vph). This volume will work nicely along a two lane roadway segment, but will create a very significant impact to the SR 49 corridor south of McKnight Way. Our Buildout traffic projections used in this study assume that such a connection is viable and will be in place. This connection provides a much needed reliever to impacts that would otherwise happen along the McCourtney corridor interfacing with the SR 20 freeway ramps, and thus the Empire Interchange. The McKnight Way Interchange is fully loaded in the street network, justifying the need for this additional connector roadway. The Empire Street interchange volumes are also reduced because of this additional connector roadway.

Need for Western Bypass

It was identified previously that the Golden Center Freeway would be over capacity around the Year 2040 as well as Buildout, and would require some relief in order to function adequately. A new roadway to the west of Grass Valley seems to be the only remaining viable alternative to mitigation above and beyond that which is already envisioned for the Grass Valley vicinity. The City of Grass Valley's recently completed Year 2020 General Plan document's circulation element did not identify this western bypass as a needed improvement for the future, possibly due to a difference in future forecasting volumes for the Buildout year, and lack of analysis of the Empire Street interchange or the Golden Center Freeway operations.

One of the purposes of this study was to refine the model to better project Year 2040 and Buildout conditions, and examine in greater the detail the projected traffic operations of the Empire Interchange and Golden Center Freeway operations for Year 2020, 2040, and Buildout conditions. The model was refined to more accurately calculate trip generation and street network assignment. The projections were analyzed in a traffic operations analysis, which included HCM merge analysis, etc. These detailed study analyses indicate that the Golden Center Freeway will fail. A reliever route north of SR 20 and Empire Street is needed, which can take some of the freeway traffic to parallel facilities.

It is possible that by constructing a "western bypass" west of the City of Grass Valley which interfaces with SR 20 west of Brighton Road that a parallel movement of traffic to that on SR 20 north of the Empire Interchange can be made possible. Previous studies for 20 year horizon traffic have shown that the Western Bypass for the City of Grass Valley is not needed due to lack of demand and ample capacity on the Golden Center

Freeway. However, with the significant increases in traffic volumes now being projected for Year 2040 and Buildout conditions at the Empire Interchange and the Golden Center Freeway, there seems to be a demand for it. The freeway will be over-capacity by the Year 2040.

We have found that at the Year 2040 and Buildout, the demand will be there, and the drivers within the study area will look to alternative routes if they are available, versus traveling on the Golden Center Freeway with stop and go traffic. With a new western bypass, the Golden Center Freeway would continue to operate at near capacity conditions, but some of that traffic could divert to the so-called western bypass from Ridge Road on the north of SR 20, as well as from McCourtney Road south of SR 20. This would free up some of the needed capacity along the freeway (which is projected to be between 10% - 20% over capacity, or between 500 - 1,000 vehicles too much). A new road could carry that amount of traffic away from the existing freeway corridor. The cost of this improvement would exceed the entire capital improvement costs now envisioned for western Nevada County. A new interchange, bridge, and road system to SR 20 west of Brighton Street would easily exceed $20,000,000.

Separate Buildout traffic model runs were tested with the Western Bypass in place as well as a full freeway interchange connection to SR 20 about a mile west of the Brighton over crossing. The model runs showed that the bypass would attract a significant amount of traffic (over 1,500 vph), which will free up some capacity along the Golden Center Freeway. The total "screen line" volumes of surface streets (such as Main Street, Bennett, and Auburn which connect to the freeway) went down approximately 600 vph, indicating that the bypass can help reduce impacts to the freeway system for Buildout scenarios. Mainline freeway volumes, however, were not significantly reduced, but the on and off-ramp volumes were, indicating that there would be an improvement to level of service and traffic flow.

In order for the bypass concept to work, 1) SR 20 would need to be improved to freeway status west of Brighton Road for a distance of approximately two miles, and 2) a new interchange connecting the western bypass would need to be constructed. The cost for these two improvements combined would easily exceed $30,000,000, or nearly three times the current capital improvement program for the entire western Nevada County area. This major mitigation is only needed if the General Plan as envisioned by the City of Grass Valley is built out. One potential mitigation of traffic impacts could be accomplished by reducing land use densities for commercial and industrial uses back to levels that pre-date the GVGPU.

Cost Estimates

Caltrans District 3 provided general cost estimate data for interchange improvements. A partial listing of the various cost factors used in developing preliminary cost estimates in this study are given in Table 6.1 below.

The cost estimate for this alternative, a SPUI at the Empire Interchange and two modern roundabouts along the Mill Street corridor would be:

- $4,608,000 for the construction of bridge ramps and improvements to the existing Empire Street interchange to convert it to a Single Point Urban Interchange (SPUI), and
- $603,300 for the two modern roundabouts on the Mill Street corridor from McCourtney Road to the SR 20 WB ramps.

The total cost for this alternative would be $5,211,300.

Table 6.1

Caltrans Construction Cost Factors and Summary for Empire Interchange SPUI Conversion (see Figure 6.2)

Construction Activity	Units of Measure	Cost per Unit*	Units in SPUI	Cost Estimate
1. Earthwork Construction				
* Roadway Excavation	Cubic Meter	$13.00	N/A	N/A
* Imported Borrow	Cubic Meter	$15.50	1400 m3	$21.7k
* Clearing & Grubbing	Lump Sum	$10,000	N/A	$10k
2. Pavement Structural Section	8800 m2 to be resurfaced		1000 m3 of new asphalt	
* Asphalt Concrete (Type A)	Tonn	$44.00	2025	$89k
* Aggregate Base	Cubic Meter	$36.00	N/A	N/A
* 25 mm OGAC	Tonn	$46.00	N/A	N/A
3. Drainage				
* Storm Drains	Lump Sum	$30,000	N/A	$30k
* Project Drains	Lump Sum	$10,000	N/A	$10k
4. Specialty Items				
* Guardrails, landscaping	Lump Sum	$250,000	N/A	$250k
5. Traffic and Minor Items, Mobilization				
* Delineation, signs, etc.	Lump Sum	$400,000	N/A	$400k
6. Roadway Additions				
* Supplemental Work	5% of items 1-5	$(0.05) x (1-5)	$810.7k	$40.5k
* Contingencies	25% of items 1-6	$(0.25) x (1-6)	$851.2k	$212.8k
7. Structures Items				
* Bridge, Viaduct, etc.	surface area sq m	$1350	2625 m2 new bridge ramps	$3.544 M
* Under crossing, Tunnel	surface area sq m	$1775	N/A	N/A
8. Right of Way Items				
* Acquisition	acre	$250,000	N/A	N/A
* Utility Relocation	Lump Sum	$1000	N/A	N/A
TOTAL				**$4,608,000**

Cost estimate factors source: Caltrans District 3

Table 6.2

Modern Roundabout Cost Summaries

(see Working Paper 5 for details)

Modern Roundabout Location	Cost Estimate (see Tables 5.2, 5.3)
McCourtney Road / Mill Street	$372,400
Mill Street / SR 20 WB Ramps	$230,900
TOTAL	$603,300

Sample CALTRANS Calculation using factors in Table 6.1:

The project below was calculated for bridge surface area using the surface area cost factor listed in Table 6.1 of $1,350 / square meter. Since the project is 8.6 miles, there would be approximately 120,000 new square meters of bridge area. Multiplying this by $1,350 the cost estimate for the structure would be $163,468,800. The cost estimate below was reported as $164,000,000, which correlates the cost estimates used in this working paper.

FACT SHEET

ROUTE 92/SAN MATEO-HAYWARD BRIDGE TRESTLE

AND EAST APPROACH WIDENING PROJECT

Project Manager **Lenka Culik-Caro**

PROJECT DESCRIPTION: In San Mateo on Route 92 from the east end of the high level portion of the San Mateo-Hayward Bridge to I-880 in Alameda County. The length of the project is 8.6 miles including 5.15 miles of the new trestle.

Current	Proposed
	

This project will widen the portion of Route 92 corridor from Route 92/880 Interchange to high-rise portion of San Mateo-Hayward Bridge from 4 to 6 lanes to alleviate existing traffic congestion, relieve projected traffic congestion, enhance safety and improve maintenance operation. The scope of the project includes a new 60 foot wide trestle on the north side of the existing trestle, widening of two structures, replacement of one structure and a new pedestrian/bicycle over crossing. The west bound high occupancy vehicle (carpool) lane will be extended and a mini-toll plaza (booths added to the west of the existing plaza to handle additional traffic without having to widen the highway) will be added.

COST ESTIMATE - $164 Million including R/W and environmental mitigation costs (1996 Estimate).

AVAILABLE FUNDING - $180 Million is programmed in the 1992 Toll Bridge Program (95/96 FY).

STATUS OF PROJECT (Current)

Source: http://svhqsgi4.dot.ca.gov/dist4/Smhb.htm

APPENDIX